



THE FUTURE WATER SUPPLY OF PHILADELPHIA.*

BY COL. WILLIAM LUDLOW,
Chief Engineer of the Philadelphia Water Department.

Vice-President FREDERICK GRAFF, introduced COL. LUDLOW, who spoke as follows:

MR. PRESIDENT, LADIES AND GENTLEMEN:—I must admit that I am somewhat taken by surprise when I received the invitation from the very excellent Secretary of the Institute, requesting me to attend the meeting to-night and make some remarks regarding the future supply of the city; I was under the impression that the meeting would resolve itself into an informal professional discussion of the matter, but I find that I am to have the field somewhat to myself and to talk to more people than I had anticipated. I know, however, that you are all interested in the subject as well as I, but I have not prepared any formal address and shall confine myself, therefore, to general remarks as to the present aspect of the important question of the future water supply of this city.

The subject is not new. I think my friend, the President, will admit that it was an old one in his early days, and it has so continued to the present. Agitation of the subject has continued for a generation past without definite conclusions being reached although we are approaching more and more closely to the necessity for reaching a decision. This futility of discussion has resulted mainly from the

* Abstract of remarks presented at the Stated Meeting of the Franklin Institute, held Wednesday, April 15th, 1885.

absence of full and accurate investigation of the real facts upon which alone a reliable and final judgment can be made. The situation is about this: Philadelphia is a city happily situated in many respects, with a great river on either side; one stream, the Schuylkill, drains a mountain region and has been looked to both to supply the water needed for municipal purposes, and even to furnish the power by which that supply should be pumped and delivered to the citizens. Hence the construction of those early water works at Fairmount, originally breast wheels, which were later converted into turbines and which have continued in service to the present day. With the growth of the city came the necessity for an increase of quantity, and from time to time the appliances for augmenting the daily pumpage have been multiplied until now there are no fewer than eleven engines at four great pumping stations drawing from the Schuylkill river into which, to a considerable extent, the waste matters of the valley are poured. On the other side of the city is a great tidal stream which receives the waste matters of the community, and at two points upon the Delaware we have been drawing these waters to supply the districts of Kensington and Frankford, but it has long been recognized that the water pumped at Kensington contained matters prejudicial to health, and the quantity of this was increasing year by year; this station has therefore been abandoned. The serious thought of those who from time to time have been charged with or interested in this vital matter of Water Supply have been turned to the consideration of the means of amending the defects of quality and quantity. There are two sources whence the city of Philadelphia can take its water, I mean practical sources as determined by engineering considerations; namely, the valley of the Schuylkill and the valley of the Delaware. The problem to be solved is whence a suitable supply both in quality and quantity can be derived to the best advantage; namely, at the lowest cost of construction and the lowest future cost of maintenance. A gravity supply is advantageous when practicable, for the reason that the water intercepted at a sufficient elevation will pass from its source to the city through the conduits, as water will flow down hill, whereas the raising of the large quantity of water required for the supply of the city involves heavy expenditure for machinery, and a constant annual charge for fuel and service.

For two years past the Department with which I have the honor to be connected, has assiduously sought to gather all the information

bearing upon this matter which was attainable by topographical and hydrographical surveys, by meteorological observations, by chemical analyses and by sanitary inspections, endeavoring to cover the entire field within which lay facts pertinent and important. Our observations are drawing to a close. About nine-tenths of the field of exploration have been covered, and I trust that within another year we shall be enabled to complete and digest the information so gathered and present to the city, and to the engineering world the results of our labor in complete shape. It was for lack of this information that previous investigations have been rendered futile. The most important report which has been made upon this subject was presented about ten yeears ago, in 1875, when in anticipation of the celebration of the Centennial, a commission of eminent engineers was gathered to consider the entire subject, taking into account both the condition of the present supply and what should be done for the future. That their report, containing most valuable information, should have resulted in inaction is largely attributable to the fact that they were without the necessary exact data for final judgment. They made the best recommendations which, under the circumstances, could have been formulated, but in the light of fuller information it is necessary to differ in some respects from the preliminary conclusion which they reached.

At present I cannot say that I am prepared to announce final conclusions as to the general solution, but it appears to lie in the choice of two projects.

Many years ago Mr. Birkinbine, who was then the Chief Engineer of the Water Department, proposed to secure a suitable gravity supply by impounding the waters of the Perkiomen Creek, the most important affluent of the Schuylkill river, which, from the supposed ample flow and purity of its drainage promised to be satisfactory and sufficient. The project contemplated the construction of a high dam near Schwencksville where the valley was narrowed and the rocky banks afforded a suitable site for a construction of this kind, and the Commission of 1875 were inclined, upon the data at their disposal, to favor this project, especially as the estimates of cost of a supply from the Delaware were vastly greater. Were we sure of ample amount and good quality, the Perkiomen project would present undoubted advantages of a high order. Unfortunately our investigations tend to show that the flow of the stream, even aided by gathering the waters of some of its affluents, is insufficient for the total quantity that Phila-

delphia will require in the near future. The Delaware project had never been carefully investigated, and for this reason: in 1883 two parties were formed, one to run a conduit line to the Perkiomen and elaborate the necessary information; the second party to run a corresponding line northward to the Delaware with the view of extending the investigation to near the Water Gap, at some elevation which should be found sufficient to permit the river to flow into the conduit and thence into the city, and the apparent probability of the insufficiency of the Perkiomen gave greater weight to the Delaware project than it had hitherto borne.

In considering the route toward the Gap, an examination of the map showed that an elevated region, designated as the South Mountain, stretching from northeast to southwest, lay across the Peninsula between the two rivers and would bar the construction of an aqueduct without extensive tunneling. A line northward from the city to the Delaware river reaches that stream at a point just below the gorge or the South Mountain, and a practicable conduit line upward could thence be made by following the valley of the stream, and thus evade the formidable obstruction which the mountain presents. Pursuing this plan, the surveyors were pleased to find, in the first place, an unexpectedly favorable line to the Delaware at Point Pleasant, half-way between Trenton and Easton, and the analysis of the water of the Delaware at this point further proved that in quality it was little inferior to the noted waters of the Gap itself.

This was our discovery. Furthermore, in proceeding northward from Philadelphia the conduit line crosses the valleys of several creeks of considerable volume—the Perkiomen, the two Neshaminies and the Tohickon—the latter stream discharging into the Delaware at Point Pleasant. The thought at once suggested itself that by utilizing the flow of these streams they could be intercepted, turned into the conduit and sent to the city by gravity, and that for a greater portion of the year the flow of these would be sufficient to supply all requirements, and that for such time as this flow should be deficient it could be made up by pumping from the Delaware itself. This, practically, constitutes a new project as compared with that of drawing water from the Gap entirely by gravity, and the expense of this construction was moderate enough to bear comparison with the Perkiomen project. It was found, for example, that the distance, in each case, was about the same, namely, thirty miles, and that the cost of construction was also

about the same, namely from \$6,500,000 to \$7,000,000. This estimate, you will understand, is that of the cost of the construction of the conduit merely, without adding other items (which will no doubt be large), for dams, land damages and other contingent expenses.

These conduits, I might say, are designed to be twelve feet in diameter with a grade of one foot in six thousand and with a capacity of delivering to the city 210,000,000 gallons a day at an elevation of 166 feet above city datum. This elevation is that of the existing Wentz Farm Reservoir, on the county line northwest from Bridesburg, and of the proposed Cambria Reservoir in the upper portion of the Twenty-eighth Ward.

With regard to this question of quantity, the following considerations present themselves: Our present pumpage is about 70,000,000 gallons a day, with a population approximating closely to a million people. A generation hence Philadelphia will contain two millions of inhabitants. The supply must therefore be doubled which would make it about 150,000,000 gallons a day. Furthermore, allowance must be made for the fact that in a large community like ours the use of water for the multiplied purposes of manufacturing and domestic uses increases in a greater ratio than the population itself. With works of the magnitude and cost of these which we have been discussing, it would be folly to project for a smaller supply than will be required within a generation, and for this reason 200,000,000 or 210,000,000 gallons were estimated for and the dimensions and grade of the conduit were thence determined.

Going back now to the question of distance and cost it will be seen that exact observation proves that for the first time the two projects, the Perkiomen and the Delaware, began to balance each other, and should the Perkiomen prove insufficient the Delaware project would practically stand alone; but in order that all possible ground should be explored I directed the examination of the upper Lehigh, a stream with which I was personally familiar from frequent journeys over the mountains to the Susquehanna Valley, and which, although so distant, possessed favorable characteristics from the purity of its water and the great elevation of its water shed. When, therefore, the Perkiomen proved of doubtful adequacy, the acute suggestion was made by Mr. Hering, who in a most thorough and capable manner has had immediate charge of these surveys, that were a sufficient amount of the waters of

the upper Lehigh brought into the upper valley of the Perkiomen a most excellent supply could thereby be secured.

You will observe that in all this matter the question of quantity has been of vital importance. We want 210,000,000 gallons a day. Now the low-water flow of the Delaware at the Water Gap in 1883 at a time when the stream was lower than it had been within the memory of the oldest inhabitant, was gauged and its flow at that time found to be about 700,000,000 gallons of most excellent quality. At Point Pleasant the volume of the river is about one-third greater than this, and in quality nearly as good as at the Gap. The Lehigh has a moderate flow. Its minimum in 1883 being about 70,000,000 gallons, but with excellent facilities for storing water at a great elevation above the reach of pollution. The bringing of this down into the upper valley of the Perkiomen would double its supply and the combination would once more have the prestige of a practicable and promising project.

At present, therefore, these two projects lie before us for consideration and ultimate decision, and, as I said before, within another year I trust that the problem will have been solved.

It may be of interest to explain how it happens that with the Schuylkill flowing past our doors all the engineers who have studied this subject seem to have concluded that at some time or other the Schuylkill River itself must be abandoned as a source of water supply. The reasons are these: The origin of the Schuylkill is in the mountains among the coal mines. The drainage from the coal measures, supplemented by the large amount of pumping from these mines constitutes a volume of acid water which fills the upper portions of the stream and is unfit either for drinking or manufacturing purposes, or even to sustain life. No fish can exist in it, nor can human beings drink it. In the course of its flow downward the Schuylkill above Reading traverses a geological belt of limestone whence considerable affluents feed the river, bringing with them a solution of the lime and the alkaline waters mingling with the acid waters of the parent stream neutralize each other and become again fit for ordinary purposes and for the existence of fish. Thereafter we have no further difficulty in this respect; that is with regard to the chemical characteristics of the water. The water as it reaches Fairmount Dam is sometimes slightly acid, sometimes slightly alkaline and sometimes neutral. But the important fact remains to be noted that the valley through its length is a populated district from end to end, and into it are poured all the waste matters of a large and busy

population ; every town and industry contributing its quota of pollution, whether sewage or the waste products of manufacturing establishments. With two great railroads extending up its banks and with communities and towns increasing year by year in number and population, the Schuylkill can be described only as an industrial valley which in the future will be densely populated, and it becomes manifest at once that unless extensive engineering constructions be planned, strict legislative enactments be passed and rigid enforcement of these laws be insured, the waters of the Schuylkill must continue to receive deleterious matters in constantly increasing quantities, and that ultimately they will cease to be available for the purposes of that great city which lies at its mouth and absorbs the contaminations of everything above.

The population of the valley above Philadelphia, at present, is in excess of 350,000, and if we are to endeavor to protect the stream from this pollution, which is not only nauseous in contemplation, but in fact dangerous to health, sewers must be built upon both banks which shall intercept and discharge all waste matters and convey them down the entire length of the valley until they can be discharged into the Delaware River below the city.

Another important fact must be observed ; within sixty years a marked diminution has taken place in the minimum flow of the stream.

Sixty years ago the summer flow of the Schuylkill was estimated at 500,000,000 gallons a day. Successive estimations of the low-water flow were made from time to time, all showing a diminution in quantity until that in 1874 determined the minimum flow as 250,000,000 gallons.

Here, then, within this period the low-water flow of the stream had decreased one-half, and, supposing that it had gone no further than was observed at the last examination, the flow of the stream when at its low stage is little more than the city will require a generation hence. It follows that with but a slight shrinkage comparatively, in the future the city would be pumping up the entire river. I do not wish to be misunderstood with regard to this, and therefore beg to explain what I mean by the minimum flow : It is not probable that the total annual flow of the Schuylkill has decreased. This flow is dependent upon the rainfall, and cannot in the absence of any marked changes in the rainfall be itself materially modified, but the destruction of the forests in its head-waters, the clearing and cultivation of lands, have to a great extent deprived the river of that power of conservation which belongs

to wood land, whereby the rainfall is held back and checked, as it were, in its passage to the stream, and the flow is more nearly equalized and prevented from dashing down and passing out. With the removal of the forests this fact ensues: The rainfall rapidly descends to the stream, creating a freshet which sweeps down the valley and passes out and is lost. During periods of drought, the rains being suspended the river shrinks, its flow becomes moderate and its movement gentle, and presently we attain the minimum discharge.

In depending upon a stream, without taking means to restrain the passage of freshets, it is manifest that we can pump no more from the river than it will daily bring to us, and the minimum flow therefore should be as carefully investigated as we would investigate the strength of the weakest link in a chain from which we intend to support a weight.

It would be possible by means of dams across the stream to impound some portion of the volume of these successive freshets until the periods of drought, which occur always in summer and frequently in winter, and to draw upon these reservoirs when required. But again that question of the pollution of the stream comes in, occasioning doubt as to whether should this be done, it might not be found in the end that large expenditures had been wasted by reason of the inferior quality of the water and the injudiciousness, of depending in perpetuity upon it. For the reasons given the water varies greatly from time to time in its chemical character, potability and wholesomeness. At times during the passage, for example, of the freshets the waters of the stream being largely the results of recent rainfall, are in good condition; at other times they are highly charged with pollution and occasionally get themselves into a condition of the most nauseous offensiveness. It is manifest that unless these difficulties can be amended the Schuylkill cannot continue to be regarded as a suitable supply for a population like this, and the vital importance to modern communities of a bountiful supply of wholesome water for all purposes is so great as to constitute one of the most serious problems relating to municipal existence, and sooner or later there is not a city in the world that has not this important matter to decide.

I have endeavored to present to you briefly the aspects of the problem precisely as they present themselves to-day. It is one in which every individual is in the highest degree interested. It is one upon which the future prosperity and welfare of this city depend.

I am very much obliged to you for your attention, and trust that some one will take up the discussion at this point.

DISCUSSION.

PROF. HOUSTON.—The exceedingly interesting remarks the gentleman has just made are enough to give thoughtful people considerable matter for reflection. The question of the water supply of any great city must always be a difficult one to solve, since as the needs for an increased amount of water grow, the ability of the ordinary means to give a large supply of pure water decrease. The rivers of any country are the natural sewers into which the dirt and filth of that country drain; and to safely take the water supply of a large city from any river requires considerable thought and skill.

The problem as to the water supply of the city of Philadelphia is one to which we have all given considerable attention. A number of years ago, I called the attention of the Franklin Institute to what I regarded as a dangerous pollution of the Schuylkill River; and I am glad to hear Col. Ludlow speak in such plain and unmistakable language concerning the probabilities of the near future of the Schuylkill. I take it that the real danger coming from drinking Schuylkill water does not exist with equal gravity all the year. During a large part of the year the lower basin of the Schuylkill, from which most of our city's supply is taken, is practically in the condition of a "steppe-lake," that is a river without an outlet.

Under these conditions, its impurity increases from the loss of pure water by evaporation. For many months in the year, the citizens of Philadelphia know that comparatively little or no water goes over the dam, and were it not for the water which goes through the locks, there would be no discharge at all except that which is pumped into our reservoirs. Under these conditions, we are actually damming up the river and drinking its contents. During many months in the year, and particularly those months when we should be the most careful of the purity of our drinking water, we are drinking something that is far from wholesome. I have not the slightest hesitation in expressing this as my opinion. During this time of the year, from a water itself impure, we pass off a large quantity of pure water by evaporation, and drink the dregs. Now we do not want the dregs of the Schuylkill, especially when in the immediate neighborhood of our pumping stations we have the outlets of sewers.

Of course, Schuylkill water cannot be as poisonous as many allege, else we would not be here. The main point, in my mind, is: Can we rely on the Schuylkill for our water supply in the near future, say for the next fifteen or twenty years? Col. Ludlow has stated the problem very clearly. The very conditions of the valley of the Schuylkill seems to render it improbable that we can continue using the water for drinking purposes.

The destruction of the forests over the upper basin of the Schuylkill, unquestionably favors the rapid drainage of the rain water; so that, for a considerable part of the year, we have so limited a supply that, as has already been shown, we endeavor to drink the entire river. Unfortunately, too, during that time in the year when the rain water would make the river comparatively wholesome, by diluting it with pure water, the rapid drainage brings down the filth and sewage accumulations from the river banks. So the very time we ought to get comparatively pure water, we get it very impure. You are probably aware of the fact that when the water looks the dirtiest, it is not necessarily at its worst. In this condition it is often less harmful than when quite clear.

I therefore thoroughly agree with the speaker that the Schuylkill cannot be relied on for our future water supply; nor to my mind can any simply impounded basin be relied on for the water supply of Philadelphia. We have in any impounded basin the very conditions going on to which I have alluded in speaking of the lower Schuylkill. If you dam up a stream and let even pure water run into it, there will be discharged into the air, as vapor, pure water and comparatively impure water will be left in the reservoir. I believe it has been the experience of almost all our large cities that have tried the impounding plan that it does not give satisfaction; not only from the disagreeable cucumber odor given to the water, but from other reasons.

The Schuylkill must undoubtedly for many years to come be looked upon as the source of our city's water supply; but, looking beyond this time, can we safely, for the next three or four generations, derive our water from this river? Were this river all we could get, of course we must go to it. That settles the question. I do not, however, believe so. It has sometimes seemed to me not such a very wild or visionary scheme to go to some magnificent natural subsidence reservoir like any of our great lakes. I know the distance is very great, but so is the population along the Atlantic seaboard. If some

plan could be devised by which our large cities could share the expense, then it does not seem to me so impracticable to look to the great lakes for our water supply.

We have other waters than the Schuylkill, however, close at hand. It is indeed a very fortunate circumstance if, as Col. Ludlow has remarked, the upper sources of the Delaware will probably, from their character, never for a long time to come be improved or cultivated. If no mineral deposits that would lead to extensive mining operations be discovered in the upper basin of the Delaware, then we may perhaps rely on the Delaware for our future water supply. But even here does not the same old question still suggest itself? Will not, in the remote future, the valley of the Delaware become densely populated and thus pollute this stream?

There is one thing which to my mind seems somewhat of a danger, and that is the discharge of the Intercepting Sewer into the Schuylkill immediately below the dam. There is scarcely opportunity for the suspended solids to do anything but settle immediately in the bed of the river. I am aware that the discharge of the sewer at this point is but a temporary expedient; but I fear we are going to permit a temporary expedient to bring a great deal of trouble on Philadelphia; a trouble that may cost much to remove.

Already some of the best sections of our city discharge their sewage into the river below the height of mean tide. On the rising of the tides the water backs up the sewer and causes a dangerous leakage of sewer gas into the houses; added to this, the prevalent southwest wind brings very unpleasant odors as it is from the lower Schuylkill; so that if we add to these sources of danger, that arising from the formation of sewage deposits in the Schuylkill at this point, the danger may become very grave. It does seem to me that this is something that we ought to be very careful about—spend a little more money if necessary—and carry the discharge a little farther below the mouth of the dam.

We have only to look at the forebay of the Fairmount Water Works to see the possibility of sediment collecting to the depth of several feet, right alongside of the inlets to the water wheels. Here, despite the velocity caused by a fall of many feet to the wheels, some six or eight feet of sediment had collected. I think there is a very great danger from similar deposits of sewage from the Intercepting Sewer, and one that ought to be attended to.

MR. GRAFF.—I hoped to have this matter thoroughly discussed among the audience present to-night. Many of them have studied it to some extent and have come to it with new light. We may sometimes look so long at an object (which is really true of painters and artists) that we lose its true proportions and have to leave it and come back to it again before we are able to see its full merit. I may probably be in that position; therefore, I feel that there may be parties here who might look on and discuss this matter with new light. I think there may be one thing said, and that is the point to which Col. Ludlow has referred: the fact that until the period when he was enabled by action of Councils to take up the matter there had never been suitable surveys made such as would enable the citizens of Philadelphia or the engineers employed to come to any positive conclusion in regard to the proper future supply of the city of Philadelphia. I am glad to say that these surveys have now been carried on for some length of time; not only have been carried on, but with the utmost care and with all the light and science that can be brought to the subject. Probably many of you realize how much there is to be considered. The developments of the day have taught us all very much more than we knew in former years; and the questions that attach themselves to this subject are so numerous and varied that it would be tiring you to go into them to-night. There are not only the surveys of the country; there are other objects besides that. We are only learning now how much of the rainfall can be utilized from a given area of county and how pure it will come to us when we get it. That matter is made variable by the condition of the country, particularly the wooded condition, the effect of cutting off the timber of the forests and all such matters. Col. Ludlow has shown you by demonstration that the Schuylkill river is now suffering from reduced volume produced by that cause. Therefore it behooves us all, and particularly those interested in the subject, to study thoroughly what may be the effect upon the Delaware and other streams suggested. Continued studies of these points have to be made when considering such a subject as this. They are now being considered. The geology and the surveys of the county examined have been so thoroughly gone over by Col. Ludlow that they are resorted to, and as far as they go, will be used for the geological surveys of the State; this is to show how thoroughly the surveys are being made. I agree with Col. Ludlow, that at this stage of the matter, it

would not be proper for any engineer to say positively what shall be the supply of the city in the future.

It is only feeling our way just yet That way has been felt very far, and probably very soon an opinion, perhaps a very accurate one, can be formed. I shall be willing to leave the matter in the hands of the Chief Engineer until these surveys have been completed and the whole subject thoroughly studied up. The balances that he tells you about of all the different plans investigated can then be made very important, but can hardly be gotten at until the surveys are completed. In the meanwhile, do what we may, we have to resort to the Schuylkill for our supply, because any comprehensive plan of supply is a work which will occupy much time. Even if we were to-day prepared to say that the Delaware is the proper source of future supply and the building of an aqueduct were determined upon to-morrow, the difficulty of getting from the State appropriations necessary to carry on such a work is so great that a number of years would elapse before it could be brought into use. Therefore, in the interim, we are obliged to do the very best that we can with the supply we get now. Prof. Houston has said, very properly indeed, that the Schuylkill has the disadvantage of being bottled up in Fairmount pool in the summer months, when the water is low and the outlets are only through the wheels at Fairmount and the locks, because at that time the pumping there has to stop and steam power take its place. Therefore the ability of the stream to purge itself from impurities is reduced just at the time when you want it to be the most pure. Another point comes in with that consideration, and that is, to-day we cannot store sufficient water in our reservoirs to give it the possibility of subsiding in any way. I think I am right in saying that the maximum storage in summer in the reservoirs is scarcely two days of the whole supply. Therefore, any discontinuance of pumping, you will necessarily see must reduce the reservoirs to so low a point as to make it very unsafe. The reservoirs are so small that the water may be said to simply go through them—in one side and out the other. No time can possibly be allowed for subsidence, whilst the storage capacity is so limited. As we have to continue using the Schuylkill the palliation, not an entire remedy, is the erection of larger reservoirs, a relief which I hope soon will have some attention. The subject of making an appropriation is now before the Legislature and possibly something will be done with it. The subject of the purity of the water in the Schuylkill (the impurity, I

should say), is one there can be no kind of doubt about. At times it is measurably pure, at others it is not so. There is no use of disguising the fact. As I said before, a little palliation might be made by ability to store water. The subject of any relief of the Schuylkill, I think, has been pretty well gone over by the Chief Engineer. It is a very serious point; when you come in any way to disturb the industries upon the Schuylkill valley, of course there will be more or less difficulties; such difficulties the Colonel has encountered, and has to a certain extent met. Protection may be insured by the sewer now building to carry the impurities below the point of supply. After all the matter comes down to obtaining the light necessary to form an early decision as to what shall be the future supply. I think the surveys now making will give us this light, and with the head we have conducting them, we are likely soon to come to a conclusion on that important point.

